Organization: Swinburne University of Technology

Title: Scaling Relationships For Biomolecules Adhesion on Polymeric Surfaces

DARPA

MTO   Simbiosys

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Project Goals

The proposed project aims at delivering scaling relationships regarding the attachment and bioactivity of biomolecules on the polymeric materials that are used for the fabircation of microfluidic devices.

Technical Approach

- Conceptual basis. The central feature of the proposed research is the dual-study of the attachment and bioactivity of biomolecules on polymeric surfaces, with both experimental and modelling techniques, in both empirical and first-principles modes.
- The first, empirical/quasi-empirical line of research aims at gathering data regarding biomolecular attachment and bioactivity on polymer surface. This line of research comprises experiments, database building, and the search of empirical correlations. 'Model polymeric surfaces' with combinatorially-different (i) grades of hydrophobicity; (ii) types and concentration of OH, NH2 and COOH groups, have been used. In accordance with the plan, the quantification of the attachment and subsequent bioactivity now uses Atomic Force Microscopy (in addition to a quartz microbalance and Attenuated Transmission FTIR). This line of research is completed with the building of an open, upgradeable database comprising experimentals results both generated within this project and published in the literature, and subsequently the finding of (quasi)empirical scaling relationships.
- The second, more fundamental line of research aims at building a predictive model (validated and tuned-up using the empirical research line above) that can be used in an engineering manner. The model is based on the deconvolution of the biomolecular surface in simpler elements (e.g. aminoacids, bases, etc.) with forces being assigned for the attraction/repulsion between the respective "patches" and the polymer surface. Furthermore, Atomic Force Microscopy is used to measure the actual forces (F-d measurements of e.g. polylysine "wrapping" a polymeric bead towards the combinatorial surface). Finally these forces are implemented in the model, which is calibrated with the empirical data from the database.

Recent Accomplishments

- The biomolecular adsorption database -freely available on the Internet- effectively doubled (~400 entries).
- An advanced predictive Langmuir-Freundlich model for bimolecular attachment, including new parameters (e.g. ionic strength) has been developed and made available on the Internet.
- Multiple methods for quantification, including AFM and calibrated fluorescent beads.
- Started experiments with 'model' pathogens on polymer surfaces.
- Simulated the shear flow effect on protein via force applied in F-d measurements with AFM.

Six-Month Milestones

Statistical comparison predictive model and adsorption database.
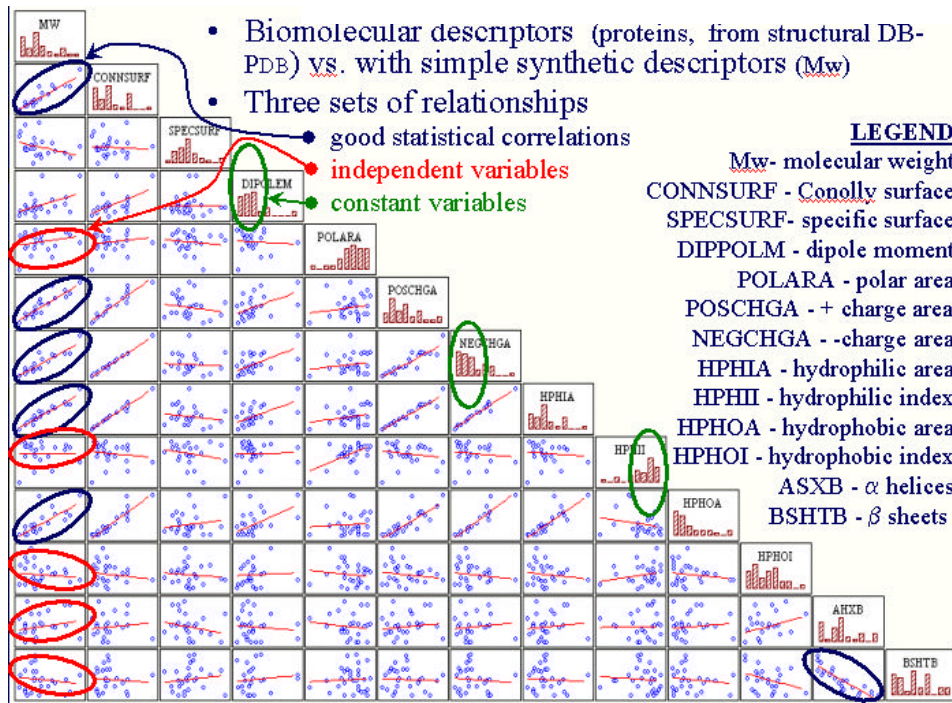
Team Member Organizations

N/A

- Biomolecular descriptors (proteins, from structural DB-PDB) vs. with simple synthetic descriptors (Mw)
- Three sets of relationships
  - good statistical correlations
  - independent variables
  - constant variables

LEGEND
Mw- molecular weight
CONNSURF - Conolly surface
SPECSURF- specific surface
DIPPOLM - dipole moment
POLARA - polar area
POSCHGA - + charge area
NEGCHGA - -charge area
HPHIA - hydrophilic area
HPHII - hydrophilic index
HPHOA - hydrophobic area
HPHOI - hydrophobic index
ASXB - α helices
BSHTB - β sheets

Figure 1. Statistical comparison of the different adhesion-relevant descriptors of biomolecules. Three classes of correlations can be found, namely (i) good statistical correlations, which allows for elimination of the respective descriptors; (ii) poor statistical correlations – the respective descriptors have independent impact on adhesion; and (iii) descriptors grouped around a statistical mean, which can be replaced by a constant value

Figure 2 (RIGHT). Statistical comparison between predicted and experimental values for the Freundlich-Langmuir model of protein adsorption on polymer surfaces.
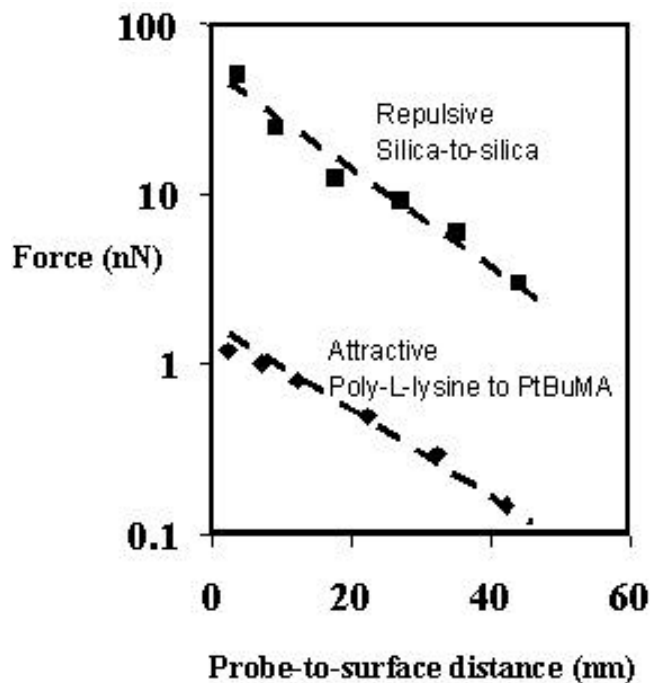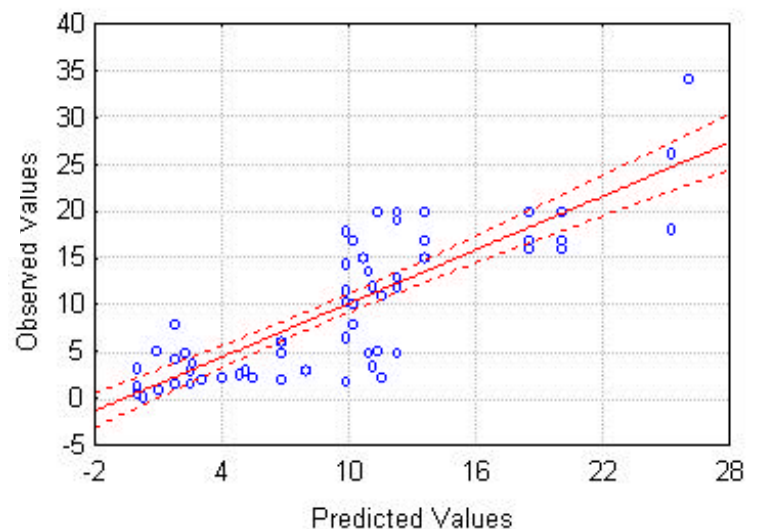

Figure 3 . Measurement of the adhesion forces between different surfaces using Force-distance analysis via AFM.
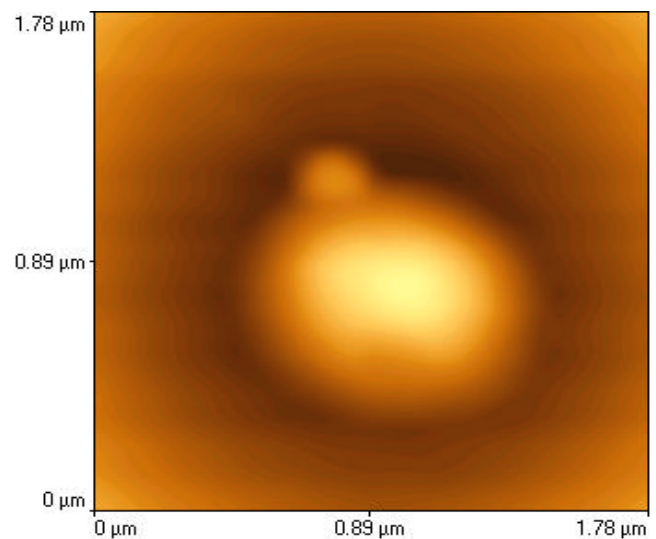
Figure 4. A topographical map of a bacterium on polymer surface via AFM.